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YIELD, STAND, AND VOLUME TABLES FOR WHITE FIR IN THE CALIFORNIA PINE REGION

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YIELD, STAND AND VOLUME TABLES FOR WHITE FIR IN THE CALIFORNIA PINE REGION[1]

FRANCIS X. SCHUMACHER[2]

INTRODUCTION

Facts concerning rate of growth and yields of the timber types to be found on a forest property (and such facts are among those of first importance for proper management of a forest) are best shown by what are known as yield tables. These tables express yields in volume, number of trees or logs, and size of tree, to be expected from stands over given periods of time.

The several types of the main timber belt of the California pine region are made up of one or more of five important species, viz.: western yellow pine (*Pinus ponderosa* Laws.), sugar pine (*Pinus lambertiana* Dougl.), Douglas fir (*Pseudotsuga taxifolia* Britt.), white fir (*Abies concolor* Lindl.), and incense cedar (*Libocedrus decurrens* Torr.). Near the upper altitudinal limits of the main timber belt, red fir (*Abies magnifica* Murr.) is also found. Western yellow pine, Douglas fir, and white fir occur in pure stands as well as in mixtures, while sugar pine and incense cedar are found in mixtures only.

A study of the growth of the mixed types may be more readily undertaken when the yields of those species which also occur pure are known. The United States Forest Service is at present conducting such studies in pure, even-aged stands of western yellow pine and Douglas fir. This bulletin presents the results of a similar study of the growth and yield of white fir.

BASIC DATA

The data upon which the tables are based are measurements of 157 normally stocked, even-aged sample plots of white fir, covering a range of age classes of from 40 to 150 years, and conditions of productivity as varied as could be found.

[1] The writer is indebted to Mr. P. D. Hanson, Associate in Forestry, who helped in gathering a large part of the data and performed most of the computational work; to Mr. H. M. Siggins, Baker Research Assistant in Forestry, and to Professors W. Metcalf and E. Fritz, who assisted in gathering data; to Mr. D. Dunning of the U. S. Forest Service, who contributed available data from 51 white fir sample plots for the yield study and 600 white fir tree measurements as the basis for the volume tables.

[2] Assistant Professor of Forestry.

1. *Plot Selection:*

In virgin timber of the California pine region, even-aged stands occur when areas, denuded by accident (such as fire, insect depredations or disease epidemics), are seeded from neighboring timber which has a good seed crop. Such areas are not common and the irregularity of their accidental stocking is a factor that limits sample plot size.

An even-aged stand is here considered to be normally stocked when the tree growth seems to make full use of climatic and soil factors, so as to produce ideal volume for site and age, both in size of individual tree and total volume. An overstocked stand may produce greater volume to the acre than a normally stocked one, but dominant individual trees may become stunted from the crowding. Conversely, an understocked stand may produce larger individual trees at the expense of total volume.

In stands which seemed to contain normally stocked areas, plot boundaries were located so as to exclude the larger blanks caused by failure of reproduction or accident, thus enclosing a comparatively complete crown canopy. No attempt was made to lay out rectangular boundaries, although acute angles were avoided. Plots were surveyed with staff compass and chain.

2. *Age Determination:*

Age of each plot was obtained with Swedish increment borers by boring to the pith, near the base of several dominant trees and counting the annual rings on the extracted core, to which was added the necessary correction for height growth to the point of boring. The age of the oldest tree was taken as the age of the plot, provided it did not vary by a significant difference (arbitrarily set at six years) from the ages of the others. When variation exceeded six years, plots were not considered even-aged and were usually not taken.

3. *Field Measurements:*

Diameters breast-high of all trees 4 inches and over were measured with diameter tape and tallied by species and crown class, and sufficient heights (of 15–25 trees) for a height-diameter curve for each important species were obtained with a Forest Service hypsometer.

A short description of physiographic features completed the field work on each plot.

4. *Office Computations:*

Number of trees, basal area, cubic volume and board-foot volume were computed by species, diameter, and crown class, and totaled for each plot. These figures were then calculated on the acre basis. Average height (i.e., height of tree of average basal area) was read from the height-diameter curve of each species on each plot (1) for all trees, (2) for trees 8 inches and over, and (3) for the dominant stand.

Volumes of individual trees were taken from volume tables for white fir.[3] The cubic-foot volume is that of entire stem exclusive of bark. The board-foot volume is that between a 1-foot stump and top diameter (inside bark) of 5 inches, based on the International Log Rule, ⅛ inch kerf.

SITE CLASSIFICATION

Site quality is classified according to the height of the average dominant white fir at 50 years of age. Average height of the dominant stand at a given age is now generally accepted as the simplest and most convenient indicator of the wood-producing power of a forest area. But the standard classification of the range of the species into three or five sites is not used. Instead, each plot was assigned a site index or number corresponding to the height, in feet, that its average dominant white fir would attain (or had attained) at 50 years. With quality of site thus definitely bound up with a given height of dominant at a given age, a universal classification for all species of the region may be adopted, into which site qualities as here defined may readily be made to fit.

Figure 1 shows the height curves used in determining site classification. These curves were constructed by fitting a form curve showing increase in height of the average dominant for the average of all sites, and a series of curves of the same form passing through ten-foot height intervals at 50 years, thus defining site classes.

The form of the curves below 40 years of age was based on measurements of individual dominant trees instead of on the average dominant of plots, because no plots under 40 years of age with trees in the 4-inch diameter class (the minimum diameter tallied) or over, were found.

[3] Volume tables in both board-foot and cubic-foot units are given on pp. 24–26.

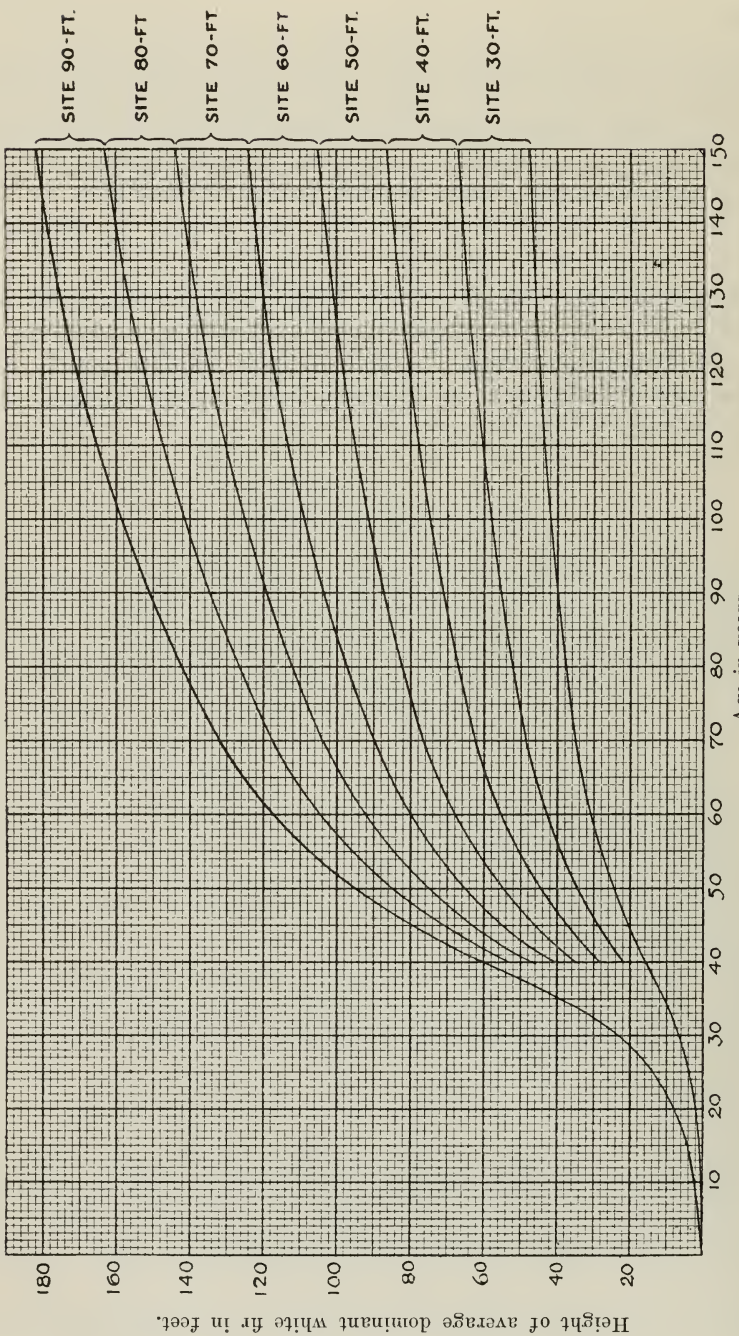

Fig. 1.—Height curves used in determining site.

YIELD TABLES

Table 1 gives the following data for the stand 4 inches and over in diameter: the number of trees to the acre, average diameter breast high, average height, basal area in square feet and volume in cubic feet to the acre, and average annual growth in cubic feet, by site and age classes. Table 2 gives corresponding values for the stand 8 inches and over in diameter, except that volume and average annual growth is given in board measure, and a column is added giving log run to the thousand feet of board measure.

DISTRIBUTION OF TREES BY DIAMETER CLASSES

Table 1 gives the number of trees to the acre and average diameter for each site and age class, but does not indicate distribution of the number by diameter classes. Complete stand tables which show such distribution would require too much space here, as a separate table would be needed for each site-age class. Analysis indicates that the distribution of trees by diameter classes is primarily a function of average diameter, so that factors of site and age influence distribution insofar only as they affect average diameter of the stand and number of trees to the acre. A single stand table, then, showing distribution of trees in per cent of the total number, when average diameter of the stand is known (table 3), serves the purpose very well.[4]

Knowing average diameter of the stand and number of trees to the acre as given in table 1, the number of trees by diameter classes may be readily computed by converting the percentages of table 3 into number of trees.

EFFECT OF NUMBER OF TREES TO THE ACRE ON YIELD

Natural stands which come in after logging, while essentially even-aged, are seldom fully stocked except on small portions of the area. But it is to be expected that as crowns of the individual trees grow and meet, forming a more or less complete crown canopy, such stands approach full stocking, not, perhaps, in number of trees to the acre for age and site, but in volume, because if the number of

[4] The method of constructing the stand table is explained on pp. 21–22.

trees is deficient as compared with tables 1 and 2, the diameter of individual trees should be greater. This is brought out in figure 2, which shows that when crown canopy is fairly complete, the number of trees which have board-foot contents (i.e., trees 8 inches and over in diameter breast high) may be but half the number given in table 2, yet in volume board measure the stand should have between 65 and 70 per cent of that given in the table.

For example, suppose a 30-year-old stand of Site 80 feet has 200 well-spaced trees to the acre averaging perhaps 2 inches in diameter breast-high. It is safe to assume, provided the area is given protection, that none of these trees will die from crowding, so that when the stand becomes 90 years old, there should still be 200 trees to the acre, all over 8 inches in diameter breast high. Table 2 gives 249 merchantable trees for this age and site. The stand, then, will be 80 per cent stocked by number of trees, and according to figure 2, 87 per cent normal by volume board measure; that is, it should contain 87 per cent of 118,000 or 103,000 feet board measure.

It seems safe to assume, also, that at 120 years the area will still have 200 trees. By that time it should be normal according to table 2, both in number of trees and in volume.

TABLE 1

NORMAL YIELD TABLE FOR WHITE FIR, INCLUDING TREES 4 INCHES AND OVER

Age	Number of Trees per Acre	Average Height of Trees	Average Diameter Breast High	Basal Area per Acre	Volume per Acre	Average Annual Growth	Basis Number of Plots
Years		*Feet*	*Inches*	*Square Feet*	*Cubic Feet*	*Cubic Feet*	
			Site index 90 feet at 50 years				
50	437	75	11.5	316	9000	180	2
60	376	93	13.6	381	12600	210	3
70	326	104	15.5	428	15200	217	1
80	285	109	17.2	458	16950	212	
90	250	115	18.5	468	18400	204	3
100	226	119	19.5	471	19600	196	
110	207	122	20.4	471	20500	186	
120	194	125	21.1	471	21300	177	
130	184	127	21.7	471	22000	169	
140	175	130	22.2	471	22600	161	
150	167	132	22.7	471	23100	154	

TABLE 1—(*Continued*)

Age	Number of Trees per Acre	Average Height of Trees	Average Diameter Breast High	Basal Area per Acre	Volume per Acre	Average Annual Growth	Basis Number of Plots
Years		*Feet*	*Inches*	*Square Feet*	*Cubic Feet*	*Cubic Feet*	
			Site index 80 feet at 50 years				
50	520	65	10.3	303	8100	162	5
60	449	82	12.2	364	11400	190	5
70	390	92	13.9	411	13700	196	7
80	342	96	15.4	441	15200	190	3
90	302	101	16.5	450	16600	184	3
100	270	105	17.5	452	17600	176	
110	248	107	18.3	452	18500	168	
120	230	110	19.0	452	19200	160	
130	218	112	19.5	452	19800	152	2
140	208	114	19.9	452	20300	145	
150	200	116	20.3	452	20800	139	
			Site index 70 feet at 50 years				
50	630	57	9.2	288	6700	135	9
60	539	71	10.9	346	9400	157	17
70	468	80	12.4	390	11400	163	8
80	410	84	13.7	418	12700	159	5
90	362	88	14.7	427	13700	152	6
100	325	91	15.6	430	14600	146	3
110	297	93	16.3	430	15400	140	3
120	275	95	16.9	430	15900	132	3
130	260	97	17.4	430	16400	126	1
140	249	99	17.8	430	16800	120	1
150	241	101	18.1	430	17200	115	
			Site index 60 feet at 50 years				
50	756	49	8.0	265	5300	106	5
60	650	61	9.5	319	7400	123	10
70	566	69	10.8	360	9000	128	10
80	497	72	12.0	387	10000	125	1
90	438	76	12.8	394	10800	120	1
100	391	78	13.6	397	11500	115	6
110	361	80	14.2	397	12000	109	4
120	336	82	14.7	397	12500	104	2
130	316	84	15.2	397	12950	100	1
140	300	85	15.6	397	13300	95	
150	290	87	15.8	397	13600	91	1

TABLE 1—(*Concluded*)

Age	Number of Trees per Acre	Average Height of Trees	Average Diameter Breast High	Basal Area per Acre	Volume per Acre	Average Annual Growth	Basis Number of Plots
Years		*Feet*	*Inches*	*Square Feet*	*Cubic Feet*	*Cubic Feet*	
			Site index 50 feet at 50 years				
50	930	41	6.8	237	3800	76	1
60	795	51	8.1	284	5300	88	3
70	690	58	9.2	320	6400	91	1
80	604	61	10.2	343	7100	89	3
90	531	63	11.0	350	7700	86	
100	477	66	11.6	352	8200	82	1
110	439	67	12.1	352	8600	78	3
120	410	69	12.5	352	8900	74	2
130	390	70	12.8	352	9200	71	2
140	374	72	13.1	352	9400	67	1
150	361	73	13.3	352	9650	64	
			Site index 40 feet at 50 years				
50	1170	34	5.6	203	2700	54	1
60	1000	42	6.7	244	3800	63	1
70	869	47	7.6	276	4500	64	1
80	760	49	8.4	296	5000	62	
90	666	52	9.1	301	5500	61	1
100	601	53	9.6	302	5800	58	
110	550	55	10.0	302	6100	55	
120	513	56	10.4	302	6350	53	
130	483	57	10.7	302	6550	50	
140	460	58	11.0	302	6700	48	
150	441	59	11.2	302	6900	46	
			Site index 30 feet at 50 years				
50	1590	26	4.4	166	2150	43	
60	1366	32	5.2	201	3000	50	
70	1180	36	5.9	227	3600	51	4
80	1036	38	6.6	243	4000	50	
90	907	40	7.1	248	4300	48	
100	815	41	7.5	249	4600	46	
110	750	42	7.8	249	4800	44	
120	700	43	8.1	249	5000	42	
130	662	44	8.3	249	5150	40	1
140	629	45	8.5	249	5300	38	
150	601	46	8.7	249	5425	36	

TABLE 2

NORMAL YIELD TABLE FOR WHITE FIR, INCLUDING TREES 8 INCHES AND OVER

Age	Number of Trees per Acre	Average Height of Trees	Average Diameter Breast High	Basal Area per Acre	Volume per Acre	Average Annual Growth	Logs per M. B. M.	Basis Number of Plots
Years		*Feet*	*Inches*	*Square Feet*	*Board Feet*	*Board Feet*		
				Site index 90 feet at 50 years				
50	284	85	13.7	290	52400	1048	20	2
60	275	100	15.6	363	81500	1358	16	3
70	260	108	17.2	418	104400	1481	13	1
80	238	114	18.6	451	122000	1525	11	
90	216	119	19.8	463	136100	1513	10	3
100	198	122	20.8	466	147800	1478	9	
110	183	125	21.6	466	156000	1418	8	
120	172	127	22.3	466	163800	1365	7	
130	163	128	22.9	466	171000	1315	7	
140	155	130	23.5	466	176700	1262	6	
150	148	131	24.0	466	181300	1209	6	
				Site index 80 feet at 50 years				
50	307	77	12.6	266	43200	864	22	5
60	305	90	14.3	339	69000	1150	18	5
70	290	97	15.8	395	89300	1275	15	7
80	270	103	17.1	430	104100	1300	13	3
90	249	107	18.1	442	117700	1308	11	3
100	229	110	18.9	446	127400	1274	10	
110	213	112	19.6	447	136100	1237	9	
120	201	114	20.2	448	142600	1189	8	
130	191	115	20.7	448	148500	1143	8	2
140	183	117	21.2	448	153000	1093	8	
150	177	118	21.6	448	157000	1047	7	
				Site index 70 feet at 50 years				
50	328	68	11.5	236	31900	638	26	9
60	334	80	13.1	310	52600	877	21	17
70	321	87	14.4	365	69600	994	18	8
80	301	92	15.6	399	82200	1027	15	5
90	279	95	16.5	414	91800	1020	13	6
100	260	98	17.2	419	100700	1007	12	3
110	243	100	17.8	422	108000	982	11	3
120	230	102	18.3	423	113100	942	10	3
130	220	103	18.8	424	118100	908	10	1
140	212	104	19.1	424	121800	870	9	1
150	207	105	19.4	425	125400	836	9	

TABLE 2—(*Concluded*)

Age	Number of Trees per Acre	Average Height of Trees	Average Diameter Breast High	Basal Area per Acre	Volume per Acre	Average Annual Growth per Acre	Logs per M. B. M.	Number of Plots
Years		*Feet*	*Inches*	*Square Feet*	*Board Feet*	*Board Feet*		
Site index 60 feet at 50 years								
50	317	60	10.4	187	20600	412	30	5
60	351	70	11.8	268	36500	608	26	10
70	348	76	13.0	322	50000	714	22	10
80	331	80	14.1	359	60000	750	19	1
90	306	83	14.9	372	67500	750	17	1
100	287	86	15.6	379	74000	740	15	6
110	272	88	16.1	383	79200	720	14	4
120	259	89	16.5	385	83600	696	13	2
130	248	90	16.9	387	88100	678	12	1
140	240	91	17.2	388	91400	633	11	
150	233	92	17.5	389	93800	625	11	1
Site index 50 feet at 50 years								
50	260	51	9.1	118	9700	194	35	1
60	341	60	10.5	206	21100	352	32	3
70	360	65	11.6	263	30500	436	28	1
80	352	69	12.5	299	37600	470	25	3
90	332	71	13.2	315	43300	481	22	
100	311	74	13.8	323	48400	484	20	1
110	295	75	14.3	327	51900	472	18	3
120	283	76	14.6	330	54800	457	17	2
130	274	77	14.9	332	57800	445	16	2
140	267	78	15.2	334	59700	426	15	1
150	260	79	15.4	336	61600	411	15	
Site index 40 feet at 50 years								
50	123	43	7.9	42	2200	44	40	1
60	265	50	9.0	117	9200	153	37	1
70	330	54	10.0	178	15700	224	34	1
80	347	58	10.9	223	21100	264	31	
90	342	60	11.5	246	25800	287	28	1
100	329	62	11.9	255	29000	290	26	
110	315	63	12.3	261	31700	288	24	
120	303	64	12.7	265	33900	283	22	
130	294	65	12.9	269	36000	277	21	
140	287	65	13.2	272	37500	268	20	
150	280	66	13.4	274	38800	259	19	

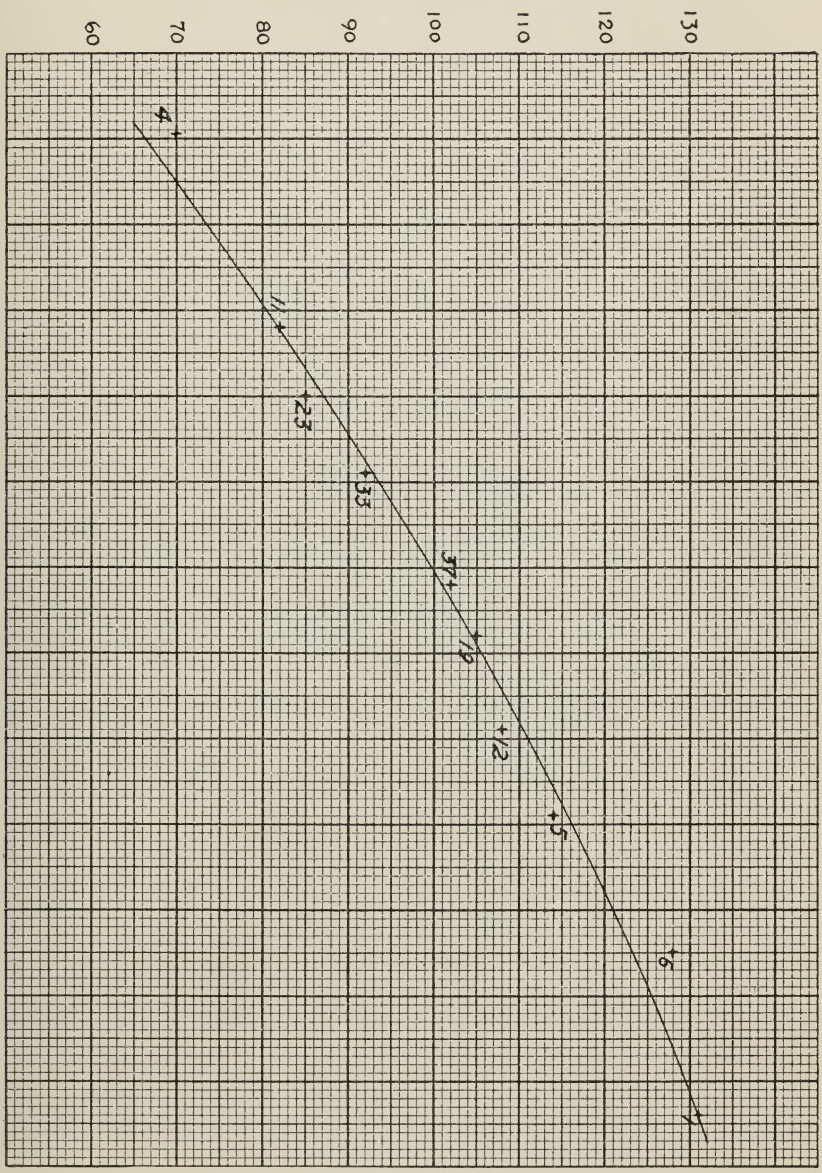

Fig. 2.—Effect of number of trees to the acre on volume board measure. (The figures along the curve represent its basis in number of plots.)

TABLE 3

DISTRIBUTION OF TREES (4 INCHES AND OVER IN DIAMETER) IN STANDS OF SPECIFIED AVERAGE DIAMETER

D. b. h. Class	Average Diameter Breast High of Stand in Inches																	
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Number of Trees in Per Cent of Total																	
4	45	30	20	16	13	11	10	9	8	7	6	5	5	5	4	4	4	4
5	32	23	19	15	14	12	10	9	7	6	6	6	6	5	5	4	4	3
6	17	19	16	14	11	10	9	8	8	8	7	6	5	5	5	5	4	4
7	6	14	14	12	10	9	9	8	7	7	6	6	6	5	5	4	5	4
8		8	12	11	10	9	8	7	7	6	6	6	5	5	5	5	4	5
9		5	8	9	9	8	7	6	6	6	6	5	5	5	4	4	4	4
10		1	6	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4
11			3	6	7	7	6	6	6	5	5	5	4	4	4	4	4	3
12			2	4	5	6	6	6	5	5	5	5	4	4	4	4	4	4
13				3	4	5	5	6	5	5	5	4	4	4	4	4	3	3
14				1	4	5	5	5	5	4	4	4	4	4	4	4	3	4
15				1	2	3	4	4	4	4	4	4	4	4	4	3	3	3
16					2	3	4	4	4	4	4	4	4	4	3	3	3	3
17					1	2	3	4	4	4	4	4	4	3	3	3	3	3
18						1	2	3	4	4	3	3	3	3	3	3	3	3
19						1	2	2	3	3	3	3	3	3	3	3	3	3
20						1	1	2	2	3	3	3	3	3	3	3	3	2
21							1	1	2	2	3	3	3	3	3	3	3	2
22							1	1	2	2	3	3	3	3	3	3	3	3
23								1	1	2	2	2	3	3	3	3	2	2
24								1	1	2	2	2	2	2	2	2	3	3
25								1	1	1	2	2	2	2	2	2	2	2

TABLE 3—(*Concluded*)

D. b. h. Class	Average Diameter Breast High of Stand in Inches																	
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Number of Trees in Per Cent of Total																	
26									1	1	1	2	3	2	2	2	2	2
27									1	1	1	2	2	2	2	2	2	2
28										1	1	1	1	2	2	2	2	2
29										1	1	1	1	1	2	2	2	2
30											1	1	1	2	2	2	2	2
31											1	1	1	1	2	2	2	2
32												1	1	1	1	2	2	2
33												1	1	1	1	1	2	2
34													1	1	1	1	1	2
35													1	1	1	1	1	1
36															1	1	1	1
37														1		1	1	1
38														1	1	1	1	1
39															1		1	1
40																1	1	1
41															1			1
42																1	1	1
43																		1
44																1	1	
45																		1
46																	1	
47																		1

DISCUSSION

One of the most important observations on the growth of white fir stands is its exceptionally slow growth up to an age of about 30 years, as shown graphically for height of dominants in figure 1, and the marked acceleration from that age up to about the 90th year, so sudden and persistent that its growth during this 60-year period compares favorably with the growth of redwood (*Sequoia sempervirens* Endl.) stands of the northern coast counties in their *first* 60 years. Bruce[5] reports that redwood probably grows faster than any other conifer and can be raised on the shortest rotation. Values from equivalent sites of the two species are compared:

	Redwood (after Bruce)	White Fir[6]
Site	III	70-ft.
Age	60	90
Average diameter breast high, in inches	14.9	14.7
Volume board measure to the acre	93,000	91,800

Perhaps advantage can be taken of the peculiar growth of white fir, so as to reduce its 90-year growth, practically all of which occurs between the 30th and 90th years, to a 60-year rotation. This plan seems feasible on areas where the species is found pure, provided the qualities of its wood can be shown to be such that it will rank with the woods of other second-growth species of the pine region. It is perhaps the most prolific seeder of the main timber belt of the region. It is considered quite tolerant of shade. These qualities adapt it to the shelterwood system of silviculture, wherein the establishment of reproduction is provided for before all of the overwood is removed. The dominant trees of this lower story should average about 16 feet in height when they are approximately 30 years old, as indicated by measurements taken beneath older timber. They will then have passed through the period of slow growth, and if given available light and space by the removal of overwood, should make the remarkable growth shown in the tables.

Even though such intensive management may not yet be practical, the slow growth of white fir in its seedling and sapling stages brings out forcibly the value of advance reproduction. Thirty years or more are lost on lands where fire destroys this young growth, or where it is heedlessly killed by present logging methods.

[5] Bruce, D., Preliminary yield tables for second-growth redwood. University of California Agr. Exp. Sta. Bul. 361, pp. 427–467, figs. 1–5. 1923.

[6] Measurements taken on young individual trees indicate that at 30 years, dominant white firs are about 16 feet high and about 2 inches in diameter breast high.

APPENDIX

DISTRIBUTION OF BASIC DATA

Measurements of 179 sample plots were available for the study, 128 of which were gathered by the staff of the Division of Forestry, University of California, and 51 by the Branch of Research of the California District, United States Forest Service.

In geographical range, these plots represent samples from practically every Sierra county between Modoc and Fresno. Distribution by watershed tributary to the Sacramento and San Joaquin Rivers, together with a number from the east side of the Sierra, is shown in table 4.

TABLE 4

Geographical Distribution of Plots

Watershed	Number of Plots
Pitt River	4
Chico Creek	1
Butte Creek	18
Feather River	41
Yuba River	6
Bear River	3
American River	21
Stanislaus River	10
Tuolumne River	43
Fresno River	4
West Side of Sierra	151
East Side of Sierra	28
Total	179

Effort was made to gather plots homogeneous in species, stocking, age, and site—a combination which is not maintained in any considerable area of natural stands—thus setting conditions that necessarily limit plot size. Table 5 shows distribution of plots by area classes:

TABLE 5

Distribution of Plots by Area Classes

Area in Acres	Number of Plots
Less than .10	25
.10–.19	65
.20–.29	41
.30–.39	27
.40–.49	13
.50–.59	5
.60–.69	0
.70–.79	1
.80–.89	1
.90–.99	1
Total	179
Average Area of Plots	.231 acres

It was found that the basal area to the acre of these plots is independent of plot area, which means that due care was exercised in laying out boundaries, and that plot areas represent the actual areas used by the enclosed stands.

Of the total number, 9 plots were discarded because they were over 150 years of age, ranging from 155 to 180, as they seemed insufficient in number for their range to put reliance in their averages. One plot, a 30-year-old one, in which all trees down to .1 inch diameter were measured, was discarded because it contained no trees as large as 4 inches in diameter breast high. The site classification of figure 1 was then based on the 169 plots thus far accepted. Information on distribution of these by site and age classes is given in table 6.

TABLE 6

Distribution of Plots by Site and Age Classes

Age	Site—Height in Feet of Average Dominant White Fir at 50 Years							
	25–34	35–44	45–54	55–64	65–74	75–84	85–94	Total
40–49		1		5	5		2	13
50–59			2	4	15	8	2	31
60–69		2	4	16	14	9	2	47
70–79	4	1	3	1	7	5		21
80–89		1		2	3	1		7
90–99			1	5	6	2	3	17
100–109			1	5	2			8
110–119			4	3	4			11
120–129	1		1	2	2			6
130–139			2		2	2		6
140–149			1	1				2
Total	5	5	19	44	60	27	9	169

Table 7 shows the average composition of the 169 plots in basal area by species.

TABLE 7

Composition of Plots

Species	Per Cent of Basal Area
White Fir	82.0
Sugar Pine	4.9
Douglas Fir	4.5
Western Yellow Pine	3.2
Red Fir	2.8
Incense Cedar	2.2
Miscellaneous	.4
	100.0

Investigation indicates that basal area to the acre is independent of composition, or at least that there is not enough of any species other than white fir to affect basal area. No appreciable error should result, then, from using white fir volume tables for all species, even though the bark of white fir is thinner than the bark of incense cedar and the pines.

REJECTION OF ABNORMAL PLOTS

In the field, plots whose crown canopies were as complete as seemed consistent with age, were considered normal and suitable as a basis for the yield tables. But the personal factor might have played such a large part in defining normality of stocking for field purposes, that a further check was necessary.

Preliminary curves of basal area growth were fitted and harmonized by site classes. Then the deviations of the basal area of each plot from the basal area curve, fitted to nearest foot of site and nearest year of age, were computed and grouped, and are shown in table 8.

TABLE 8

Deviation of Plot Basal Area from Basal Area Curve

Per Cent Deviation	Number of Plots
−50 to −59	0
−40 to −49	1
−30 to −39	7
−20 to −29	17
−10 to −19	22
0 to −9	37
0 to +9	36
+10 to +19	22
+20 to +29	13
+30 to +39	12
+40 to +49	0
+50 to +59	2
Total	169

The probable error was computed to be ± 12.6 per cent; that is, the basal areas of half the plots deviate from the curved basal area for site and age by less than 12.6 per cent, and half by more. Three times the probable error (in this case about 38 per cent) is commonly used as the limit of error, so that plots whose deviations exceeded ± 36 per cent were scrutinized, and accepted or rejected by other facts gathered from composition, plot description, etc. Twelve plots were rejected for the following reasons:

Overstocked	6
Understocked	2
Too high percentage of cedar	2
Too high percentage of Douglas fir	1
Too high percentage of sugar pine	1

The remaining 157 plots were used as the basis of the yield tables.

RELATION BETWEEN HEIGHTS OF THE VARIOUS SPECIES IN MIXTURE

This relationship was studied between the dominant trees of white fir and other species, on those plots where there was a sufficient number of another species for its height-diameter curve. Heights of the average dominants of associated species in percentage of average dominant white fir together with their coefficients of correlation are shown in table 9.

TABLE 9

Relation Between the Heights of Average Dominants of White Fir and Associated Species

Species	Per Cent of White Fir Height	Coefficient of Correlation	Basis Number of Plots
Sugar pine	92	.94±.01	30
Western yellow pine	100	.92±.05	14
Red fir	99	.88±.05	11
Douglas fir	94	.48±.16	10

There is very good correlation between white fir on the one hand, and sugar pine, western yellow pine and red fir on the other. With Douglas fir, however, the value of the coefficient is nullified by its high probable error, so that it is assumed that for this species the samples on which the correlation is based was not adequate.

Since western yellow pine and red fir make practically the same height growth as white fir on the same sites and within the age limits of the data (45 years to 150 years), one site classification, based on height of average dominant should serve for these three species. Another classification will be needed for sugar pine and perhaps for Douglas fir.

BASIS OF THE STAND TABLE

Progressive steps in the construction of table 3 were as follows:

(1) Plots were sorted by 10-foot site classes and 10-year age classes, and distribution of trees to the acre by diameter classes for each site-age class was computed in cumulative per cent. Table 10 shows an example of the computation for a random site-age class.

TABLE 10

DISTRIBUTION OF NUMBER OF TREES TO THE ACRE FOR SITE 80-FT., 50-YEAR AGE CLASS

(Average diameter breast high 11.2 inches. Basis 5 plots.)

D. b. h. inches	Average number of trees to the acre	Per cent of total number	Cumulative per cent
4	34	7	7
5	58	12	19
6	42	8	27
7	51	10	37
8	38	8	45
9	38	8	53
10	38	8	61
11	36	7	68
12	12	2	70
13	24	5	75
14	22	4	79
15	23	5	84
16	18	4	88
17	19	4	92
18	9	1.8	93.8
19	12	2	95.8
20	3	0.6	96.4
21	9	1.8	98.2
22	4	0.8	99.0
23	1	0.2	99.2
24	3	0.6	99.8
25	1	0.2	100
Total	495	100	

(2) Values of each site-age class were plotted on ordinary cross-section paper, cumulative per cents over their corresponding diameters breast high, and the points connected by straight lines. (They were first plotted on arithmetic probability paper, as proposed by Bruce,[7] but as the distribution was obviously not normal, and the use of the paper actually distorted interpolated values in the lower diameter classes, the method was abandoned). The striking similarity in form of the curves regardless of site or age, as shown by close checks between deciles for stands which had the same average diameter though differing widely in site and age, indicated that the distribution was a function primarily of average diameter.

(3) These curves were then grouped by average diameter breast high; and for each 1-inch class, deciles and the 98th percentile were averaged and plotted as shown in figure 3.

(4) Deciles and the 98th percentile were harmonized and table 3 constructed.

As a check, the coefficient of correlation between average diameter breast-high and the 50th and 90th percentiles were computed and found to be as follows:

Average diameter breast high and 50th percentile, $.83 \pm .02$.

Average diameter breast high and 90th percentile, $.99 \pm .01$.

VOLUME TABLES FOR WHITE FIR

Tables 11, 12, and 13, volume tables for white fir, were constructed as a preliminary step in the yield study. They are based on taper measurements of over 600 trees, taken by the United States Forest Service in Siskiyou County in 1905.

[7] Bruce, D., A method of preparing timber-yield tables. Jour. Agr. Research, 32: 543–557, figs. 1–8. 1926.

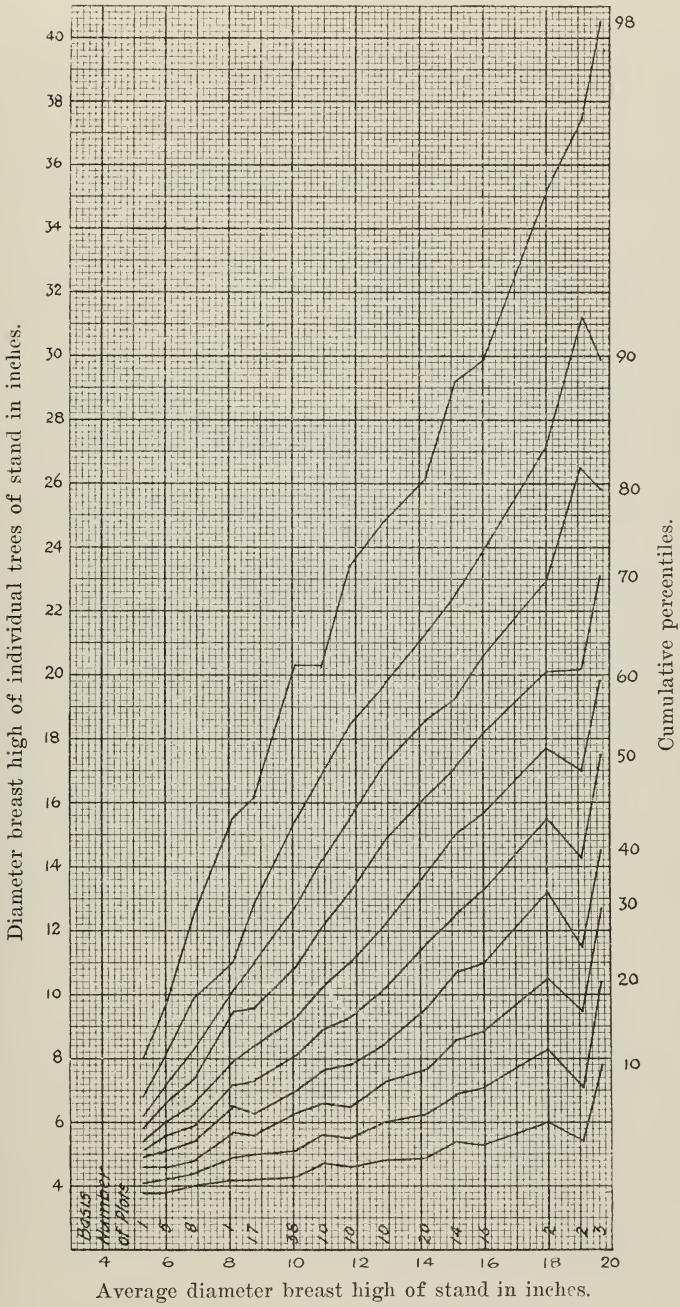

Fig. 3.—Distribution of diameter classes in stands of specified average diameter breast high.

TABLE 11

Volume Table for White Fir

DBH	Merchantable height in 16.3 foot logs to 5 inch top																Basis Number of Trees	Frustrum Form Factor	Average Height Logs
	1⅛	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9			
	Volume in board feet																			
8	19	25	34	45	54													49	.84	1.5
9	21	28	41	54	67	80												53	.87	1.9
10	22	31	47	64	81	97												57	.89	2.3
11	23	34	55	73	95	114	135	154	176									54	.91	2.7
12	24	37	60	84	108	131	156	180	206									41	.93	3.1
13		39	68	95	124	150	178	208	236	266								46	.94	3.4
14			75	106	140	171	204	236	270	303								42	.95	3.8
15			83	119	156	193	230	267	305	344								34	.96	4.1
16			91	133	175	215	258	300	343	386								29	.96	4.4
17			100	145	192	238	286	332	381	429	477	526						22	.96	4.8
18			109	157	210	261	314	367	418	472	527	581						15	.96	5.1
19					231	286	346	401	461	520	580	638						15	.96	5.4
20					251	312	375	437	502	566	631	696						12	.96	5.6
21					274	341	410	478	550	620	693	765						8	.96	5.9
22					297	370	445	522	598	675	755	832						9	.96	6.1
23					324	405	486	567	656	742	828	914	990	1065	1155	1240		9	.97	6.3
24					348	436	525	613	705	797	891	980	1065	1155	1250	1340		9	.97	6.6
25					376	470	568	665	767	865	967	1070	1165	1265	1260	1460		5	.98	6.8
26							616	721	831	940	1050	1160	1265	1375	1485	1585		6	.99	7.0
27							667	781	902	1020	1140	1260	1380	1500	1610	1730		4	1.00	7.2
28							720	844	971	1100	1230	1355	1485	1605	1740	1860		2	1.01	7.4
29							779	916	1050	1185	1325	1460	1590	1735	1870	2000		4	1.02	7.5
30							836	981	1120	1280	1420	1575	1720	1865	2010	2160	2310		1.03	7.7
31									1205	1375	1530	1685	1840	2000	2160	2320	2480	1	1.04	7.9
32									1280	1445	1625	1790	1955	2120	2290	2460	2630	3	1.04	8.0
33									1360	1540	1715	1905	2080	2260	2435	2630	2800	4	1.04	8.2
34									1435	1625	1820	2010	2200	2380	2580	2770	2960		1.04	8 3
35									1520	1715	1915	2120	2320	2520	2720	2910	3120	1	1.04	8.5
36									1600	1810	2020	2240	2450	2650	2860	3080	3290	1	1.04	8.6
37									1685	1905	2130	2350	2570	2800	3020	3250	3460		1.04	8.7
38									1770	2010	2240	2480	2710	2940	3180	3410	3650	1	1.04	8.9
39									1860	2110	2350	2600	2850	3100	3350	3590	3840		1 04	9.0
40									1945	2200	2470	2730	2990	3240	3500	3760	4020		1.04	9 1
	Total																	536		

Stump height 1 foot.
Trees scaled in 16 foot logs with 0.3 foot trimming allowance to 5 inches d. i. b. in top, International rule (⅛ inch kerf).
Table prepared by frustrum form factor method from taper curves for height and diameter class.
Basis 536 trees, 25–150 years old at breast height, measured by U. S. Forest Service in 1905 near McCloud, Siskiyou County, California.
Check against basic data shows aggregate error of 30/100 of 1 per cent, and average deviation of 7.5 per cent.
Heavy lines in the table show limits of basic data.

TABLE 12

VOLUME TABLE FOR WHITE FIR

DBH	TOTAL HEIGHT IN FEET														Basis Number of Trees	Average Height Feet
	40	50	60	70	80	90	100	110	120	130	140	150	160	170		
	VOLUME IN BOARD FEET															
8	17	23	32	42	52										49	52
9	21	30	43	55	67	79									53	58
10	25	39	54	69	86	103	118								57	64
11	29	46	65	85	106	127	147	168							54	69
12	33	53	77	101	127	151	177	203							41	74
13	37	63	90	118	149	180	211	241	272						46	79
14		73	105	140	175	211	247	283	318	354					42	84
15		83	122	162	203	244	285	327	369	410					34	89
16		94	140	185	233	280	325	374	420	468					29	94
17		105	157	208	260	314	366	422	475	531	585				22	99
18		118	174	232	290	350	412	470	533	593	654				15	103
19				257	324	392	458	525	594	660	727				15	107
20				282	355	429	503	576	652	725	800				12	111
21				311	390	472	554	636	720	804	885				8	115
22				340	426	515	607	698	790	882	972				9	119
23				372	469	567	666	764	863	961	1060	1155			9	122
24				404	508	615	722	829	936	1045	1150	1255	1365		9	126
25				439	554	672	790	907	1025	1145	1260	1375	1490		5	129
26				479	604	732	860	990	1120	1250	1375	1505	1630		6	133
27					652	793	935	1075	1215	1360	1500	1640	1780		4	136
28					707	858	1010	1160	1315	1470	1620	1770	1920		2	139
29					768	930	1090	1255	1420	1585	1745	1910	2070		4	143
30					826	1005	1180	1355	1535	1710	1880	2065	2240	2420		146
31							1265	1450	1645	1835	2030	2220	2410	2600	1	148
32							1340	1545	1750	1955	2155	2355	2560	2760	3	151
33							1430	1650	1865	2080	2300	2515	2735	2950	4	154
34							1515	1740	1975	2205	2435	2665	2895	3130		157
35							1600	1840	2085	2330	2579	2810	3055	3290	1	159
36									2205	2460	2710	2970	3225	3480	1	162
37									2320	2590	2865	3140	3410	3680		164
38									2445	2730	3015	3295	3580	3860	1	166
39									2570	2870	3170	3475	3775	4080		168
40									2690	3000	3320	3635	3950	4270		170
	Total														536	

Stump height 1 foot.
Trees scaled in 16 foot logs with 0.3 foot trimming allowance to 5 inches d. i. b. in top by International rule (⅛ inch kerf).
Basis: From table giving height in logs by study of length of top above 5 inches d. i. b. for various diameters and lengths.
Heavy lines in the table show limits of basic data.

TABLE 13

Volume Table for White Fir

DBH	TOTAL HEIGHT IN FEET																		Basis Number of Trees	Average Height Feet
	25	30	35	40	45	50	60	70	80	90	100	110	120	130	140	150	160	170		
	VOLUME IN CUBIC FEET																			
4	0.85	1.05	1.24	1.43	1.59															26
5	1.26	1.55	1.85	2.16	2.48	2.77	3.37													33
6	1.78	2.16	2.56	3.00	3.46	3.89	4.80	5.62												39
7		2.87	3.37	3.94	4.53	5.15	6.34	7 52											54	45
8		3.66	4.38	4.98	5.72	6.51	8.11	9.58	11.2	12.7									64	51
9			5.35	6.14	6.99	7.94	9.96	12.0	13.9	15.8									53	57
10				7.44	8.44	9.47	11.8	14.4	16.8	19.2	21.9								57	63
11				8.84	9.98	11.2	13.8	16.7	19.9	22.8	25.7	28.4							54	69
12				10.4	11.7	13.1	16.0	19.1	23.0	26.6	30.0	33.4							42	74
13				12.1	13.6	15.1	18.4	21.8	26.1	30.5	34.9	38.8	42.6						45	80
14					15.6	17.4	21.0	24.8	29.2	34.6	39.6	44.3	49.0	53.2					42	85
15					17.7	19.8	23.9	28.1	32.7	38.6	44.6	50.2	55.6	60.6					34	90
16						22.4	26.9	31.6	36.6	42.4	49.5	56.3	62 5	68.4					29	95
17						25.2	30.2	35.4	40.8	47.0	54.5	62.6	69.8	76.7	83.2				22	99
18						28.1	33 7	39.4	45 4	51.8	59.7	68.9	77.6	85.4	92.6				15	103
19							37.6	43.9	50.4	57.3	65.4	75.8	85.6	94.5	103				16	108
20							41.6	48.3	55.5	63.2	71.6	82.4	93.9	104	113				11	112
21							45.7	53.2	60.8	69.0	77.7	88.4	102	114	124				8	115
22							50.0	58.3	66.5	75.4	84.7	95.1	109	123	136	147			9	119
23								63.6	72.8	82.2	91.8	103	117	133	147	160			12	122
24								69.3	79.1	89.5	99.8	111	125	143	159	174	187		9	126
25								75.3	86.0	96.7	108	120	134	153	171	187	202		6	129
26								81.3	92.9	104	116	129	143	162	183	201	218		6	132
27									100	112	125	139	153	172	194	215	233		4	135
28									108	121	135	149	164	183	206	230	251	270	2	138
29									116	130	145	159	176	194	218	245	267	289	4	140
30									124	140	155	171	188	207	231	261	286	308		143
31											165	182	200	220	243	275	303	328	1	145
32											176	194	213	233	257	290	321	348	2	148
33											187	206	226	247	271	304	339	368	4	150
34											198	218	238	261	285	319	357	389		153
35											210	231	253	276	302	335	376	411	1	155
36													268	291	317	351	394	432	1	157
37													282	308	334	367	411	455		159
38													297	323	352	384	427	475	1	161
39													313	341	369	401	444	496		163
40													329	358	388	421	462	517		165
	Total																		608	

Prepared by the Form Factor Method.
The volume is total cubic volume of the stem, including stump and top, but excluding bark.
Basis: 608 trees, 25–150 years old at breast height, measured by the U. S. Forest Service in 1905 near McCloud, Siskiyou County, California.
Check against basic data shows aggregate error of 55/100 of 1 per cent and average deviation of individual trees of 8.0 per cent.
Heavy lines in the table show limits of basic data

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